ESD-TDR-65-47

Quarterly Progress Report

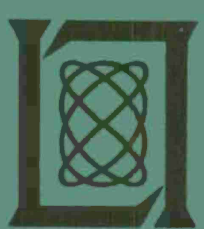
Division 2

Data Systems

15 February 1965

Prepared under Electronic Systems Division Contract AF 19(628)-500 by

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Lexington, Massachusetts



The work reported in this document was performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology, with the support of the U.S. Air Force under Contract AF 19(628)-500.

Quarterly Progress Report

Division 2

Data Systems

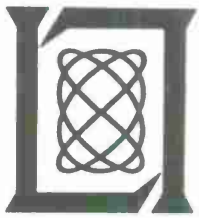
15 February 1965

Issued 12 March 1965

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts



INTRODUCTION

This report reviews progress during the period 1 November 1964 through 31 January 1965 for the General Research Program of Division 2. Separate progress reports on the Ballistic Missile Re-entry Systems, Project Apollo, and Project PRESS describe other work in the Division during the period. All the work of Groups 21 and 22 and some of the work of Groups 23, 25, and 28 is therefore reported separately.

Detailed reports of research will continue to be available in the form of Technical Reports, Technical Notes, and Journal Articles. A list of the reports issued during the present reporting period is included here.

F. C. Frick
Head, Division 2

S. H. Dodd
Associate Head

31 January 1965

Accepted for the Air Force
Stanley J. Wisniewski
Lt Colonel, USAF
Chief, Lincoln Laboratory Office

TABLE OF CONTENTS

UNCLASSIFIED REPORTS BY AUTHORS IN DIVISION 2

15 November 1964 through 15 February 1965

PUBLISHED REPORTS

Technical Report

TR No.				DDC and Hayden Nos.
364	Spin-Wave Effects in the Magnetization Reversal of a Thin Ferromagnetic Film	K.J. Harte	27 August 1964	DDC 610068

Technical Note

No.				
1964-64	Algorithms for Estimating a Re-entry Body's Position, Velocity and Ballistic Coefficient in Real Time or for Post Flight Analysis	F.C. Schweppe	3 December 1964	DDC 609524 H-626

Journal Articles*

JA No.			
2324	A Proposal for an Associative Memory Using Magnetic Films	J.I. Raffel T.S. Crowther	Trans. IEEE, PTGEC EC-13, 611 (1964)
2404	A $\lambda/4$ and $\lambda/2$ Shift Method for Elimination of Unwanted Wall-Echoes in Radar-Anechoic Chambers	J.H. Halberstein P.C. Fritsch	Proc. IEEE (Correspondence) 52, 1743 (1964)
2415	On the Fuel-Optimal Singular Control of Nonlinear Second-Order Systems	M. Athans M.D. Canon	Trans. IEEE, PTGAC AC-9, 360 (1964)

* * * * *

UNPUBLISHED REPORTS

Journal Article

JA. No.			
2502	Criticism of a Recent Article by Kinchla and Atkinson	A.I. Schulman	Accepted by Psychonomic Sci.

*Reprints available.

Meeting Speeches*

MS No.			
1165	Thickness Dependence of Creep Switching in Magnetic Films	G.P. Gagnon T.S. Crowther	Decennial Conference on Magnetism and Magnetic Materials, Minneapolis, Minnesota, 16-19 November 1964
1186	Lorentz Microscopy of Small Magnetic Particles	M.S. Cohen	
1187	Spin-Wave Effects in Magnetic-Film Switching	K.J. Harte	
1188	Light Switch Design Using Thin-Film Magneto-Optics	D.O. Smith	
1189	Uniaxial Anisotropy Spectrum in Nonmagnetostrictive Permalloy Films	D.O. Smith G.P. Weiss	
1215	The Longitudinal Kerr Effect Using a Very-Thin Fe Film	D.O. Smith	
1173	Graphical Communications and Control Languages	L.G. Roberts	Second Congress on the Information System Sciences, Hot Springs, Virginia, 22-25 November 1964
1240	Experiments on Systems	J.L. Morey† D.B. Yntema	
1224	Thin-Film Magneto-Optics in Information Processing	D.O. Smith	Symposium on Optical and Electro-Optical Information Processing Technology, Boston, 9-10 November 1964
1225	The Design of 2-3 Gc NPN Silicon Transistors for Micro-circuits	R.L. Luce†	1964 Electron Devices Meeting, Washington, D.C., 29-31 October 1964
1231	Direct Methods in the Theory of Optimal Control	P.L. Falb	Seminar, University of Michigan, 9 November 1964; Systems Theory Seminar, Stanford University, 12 November 1964.
1296	Some Current Work in the Borderland Between Perception and Memory	D.B. Yntema	Colloquium, Kent State University, 21 January 1965

* Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

† Author not at Lincoln Laboratory.

ORGANIZATION

DIVISION OFFICE

Frederick C. Frick, *Division Head*
Stephen H. Dodd, *Associate Head*
Jonathan T. Huntington, *Assistant*
Oliver G. Selfridge*

GROUP 21

Ovide V. Fortier, *Leader*
Leo J. Sullivan, *Associate Leader*
Leo C. Wilber, *Associate Leader*

E. Barsack
L. E. Bird
L. F. Cianciolo, Jr.
G. Farrell, Jr.
A. H. Flink
P. C. Fritsch
E. O. Gronroos
J. H. Halberstein
P. J. Harris
R. M. Horowitz
R. E. Hubert
H. L. Kasnitz
R. M. Martinson
E. J. Peters
D. F. Sedivec
G. M. Shannon
E. F. Tarbox
D. S. Turck
C. W. Uskavitch
F. S. Weinstein
F. A. Wilson

GROUP 22

V. Alexander Nedzel, *Leader*
William Z. Lemnios, *Associate Leader*
Walter I. Wells, *Associate Leader*

D. Batman
R. J. Bergemann, Jr.
D. F. Clapp
J. D. Cremin
E. L. Eaton
A. Freed
G. S. Gordon
A. A. Grometstein
A. B. Gschwendtner
J. H. Hartogensis
R. C. Holland
C. Hopkins
L. Kraff, Jr.
M. S. Macrakis
M. H. Malone
L. M. Meixsell
P. Mode*
L. J. Murray
H. D. Neumann
C. E. Nielsen, Jr.
J. H. Pannell
E. W. Pike
D. Reiner
J. Rheinstein
J. Salerno
B. J. Schafer
J. R. Sklar
A. F. Smith
J. L. Warner
P. A. Willmann
A. J. Yakutis

GROUP 23

Jack I. Raffel, *Leader*
Jack L. Mitchell, *Associate Leader*

A. H. Anderson
P. E. Barck
R. Berger
H. Blatt
T. S. Crowther
D. J. Eckl
A. G. Faulkner*
J. Feldman
P. A. Fergus
C. D. Forgie
J. M. Frankovich
E. A. Guditz
J. S. Heart†
T. O. Herndon
W. Kantrowitz
K. H. Konkle
C. J. Kurys
J. E. Laynor
C. S. Lin
Lo, Yi-Chao Mei†
D. Malpass, Jr.
C. E. Molnar*
M. L. Naiman
C. A. Norman
S. D. Pezaris
L. G. Roberts
D. R. Slutz*
W. R. Sutherland‡
A. Vanderburgh, Jr.
C. E. Woodward

GROUP 24

Donald O. Smith, *Leader*

M. S. Cohen
R. W. Davies
K. J. Harte
E. E. Huber, Jr.
R. C. Johnston
C. T. Kirk, Jr.
L. A. Ladd*
G. P. Weiss

GROUP 25

Douwe B. Yntema, *Leader*

J. W. Forgie
M. L. Groves
W. P. Harris
L. Klem
C. K. McElwain
R. R. Mitchell†
R. T. Mitchell
M. A. Morfield
A. I. Schulman
G. M. Schulman
A. N. Stowe
B. W. White*
R. A. Wiesen

GROUP 28

Jack A. Arnow, *Leader*
John F. Nolan, *Associate Leader*

A. W. Armenti
C. R. Arnold
T. C. Bartee†
F. Belvin
R. N. Davis
P. L. Falb
J. J. FitzGerald
L. A. Gardner, Jr.
D. L. Kleinman*
H. K. Knudsen
B. M. Lee
O. A. Z. Leneman
J. B. Lewis
H. E. Meily
A. J. Morency
H. C. Peterson
F. C. Schweppe
J. M. Winett‡
P. E. Wood, Jr.
P. M. Wortman*

---

* Leave of Absence
† Part Time
‡ Staff Associate

DIGITAL COMPUTERS
GROUP 23

I. COMPUTER SYSTEMS

A. TX-2 System

Major changes have been made to the TX-2 computer during the past quarter. When these and additional changes are completed, it will make the TX-2 better suited to multiprogrammed, multiaccess usage. Multiprogrammed, as used here, may be defined as the interleaved execution of a number of active programs, several of which may be simultaneously resident in core storage; multiaccess is defined as the capability for several programmers to communicate with their active programs.

The Univac Fastrand drum file memory was installed in mid-October, and provides 400 million bits of storage. The main core storage was enlarged by two 16,384-word modules of 2-μsec magnetic core memory. This enlargement allows for both the increased size of graphics programs and the storage requirements of the supervisor program needed for multiprogrammed operations. The speed of these new core memories will also permit the main frame cycle time of the TX-2 to be reduced to approximately three microseconds, about half the time required for the present vacuum-tube-driven 65,536-word memory.

In order to further facilitate multiprogrammed operations, two TX-2 program sequences have been given a new meaning. All user programs will be executed in Sequence 62, and only a restricted class of instructions will be permitted for user programs in order to prevent a Sequence 62 program from disturbing supervisor program activities in other sequences. The attempted execution of a forbidden instruction in Sequence 62 or the occurrence of one of a broad class of programming errors in any sequence causes an immediate change to Sequence 32 which can sense various error and other state indicators. This new structuring of the TX-2 permits supervisor programs to monitor dynamically a large class of program errors.

Another addition has been an automatic block transfer control for some of the TX-2 input-output devices. This control increases the time available for computation sequence programs by reducing the time required for input-output data transfers to a single memory cycle; only block transfer termination signals require input-output sequence program operation. This control will be used by the supervisor program to operate high data rate devices such as the magnetic tape and drum. Although the control is fully operational, the TX-2 main frame modifications required by the control will not be completed until next quarter.

B. Symbolic Page-Address Transformation

SPAT equipment* has been installed in the TX-2 and is operating. This system uses a 64-register transistor flip-flop memory, a 1024-word magnetic film memory and 100-Mcps circuitry to realize a two-stage dictionary lookup process. The core storage address is transformed from the "symbolic" value specified in the user program to the "actual" value corresponding

* Division 2 Quarterly Progress Report, Lincoln Laboratory, M.I.T. (15 February 1964), DDC 432493.

to the location in the core memory assigned by the supervisor program to the user program. The SPAT system allows the supervisor program to break other programs into 256-word pages at load time, and to scatter these throughout storage in available unused pages. The used pages are tied together by the symbolic page-address dictionary to preserve the address relationships required by the program. The system also permits sharing of data and program blocks by different programmers, restricts program activity to the area of core storage allotted to it, and detects violations of a number of additional rules which limit the ways in which storage can be used by a program. The SPAT hardware accomplishes this operation in the manner described below.

The 6-bit sequence number is encoded into a 4-bit number which is combined with the upper two bits of the 17-bit memory address to select one of the registers in the 64-word location and boundary memory (LBM). This register contains the location of the beginning of a block of registers in the 1024-word page-address memory (PAM) and a boundary value which specifies the length of the block. One other control bit specifies whether or not other control bits in PAM should be examined.

The next seven high-order bits in the original address, the "symbolic page" number, are added to the PAM block location pointer to select a particular register within the PAM block. This register contains a 9-bit "actual page" number which is adjoined to the remaining eight bits of the original address to obtain the new 17-bit actual, transformed address of the desired register in the core memory. Two other control bits in the PAM register restrict the ways in which the core memory register can be used, and a third bit indicates whether the core register can be changed by the instruction.

This address transformation occurs on every TX-2 memory operand or deferred address word cycle, but adds no time to the cycle, since it is completely overlapped with other cycles of the computer. The transformation occurs on instruction cycle only when a sequence change, a jump instruction, or a page boundary crossing occurs. At these times, 0.8 μsec is added to the cycle time. This time will eventually be reduced to 0.4 μsec.

C. Optical Input

The temporary circuitry that has been in use since the middle of last summer has been cleaned up. In particular, power supply ripple and stray 60-cps field from other sources have been reduced, and the circuitry for driving the mercury vapor and fluorescent light sources has been improved. Programming efforts have been directed at aiding alignment of the circuits and improving the primitive display programs previously written. On-line data indicate that photocathode uniformity is not so good as expected. However, it appears that this can be minimized by restricting the actual use to an area of the photocathode which avoids certain "hot spots" found near the edges.

A lens for the dissector camera has been ordered and future on-line testing should give us a much better idea of how the camera can function as a computer-operated scanning device. In the next quarter, an effort will be made to write a new input routine for the L. G. Roberts picture-processing programs.* Considerable programming time can be saved by putting the input data into the form that Roberts uses and taking advantage of existing programs.*

*L. G. Roberts, "Machine Perception of Three-Dimensional Solids," Technical Report 315, Lincoln Laboratory, M.I.T. (22 May 1963), DDC 413529.

D. Multi-User Consoles

Remote control boxes for two output typewriters have been completed and are ready to be checked out. Logic drawings have been completed for the main control logic for these typewriters and the equipment is under construction.

E. TX-2 Magnetic Tape System

Circuits for computer program selection of TX-2 magnetic tape units have been installed. At present, two units are available and four more have been ordered.

Experiments with the new magnetic tape heads and writing circuits indicate that doubling the present tape speed of 52 inches per second (ips) for writing is possible.

II. CIRCUIT DEVELOPMENT

A. UHF Switching Transistors

1. High-Speed Silicon Transistors

The transistors received from Philco which feature multiple 0.1-mil emitter and base stripes have exhibited values of f_t somewhat over 2 Gcps, but not so high as calculations predict. Measurements made during the past period have indicated that there are contact problems at all electrodes. These problems are understood and solutions are expected to be straightforward. It is anticipated that the next group of devices will have improved performance.

2. Measurements

The automatic f_t plotter has operated very satisfactorily. Plots of f_t are obtainable from 0.1- to 1000-ma collector current at measurement frequencies ranging from 100 to 1000 Mcps This means that f_t values as high as 20 Gcps may be measured. The equipment is being rebuilt in a more permanent form.

The servo loop used in the f_t system is also useful for making h_{rb} measurements. An automatic plotting system is not practical, because the r'_b and C_c values must be calculated from the measured voltage ratios.

A further effort has been made to examine the high-current anomalies in both r_b and C_c without resorting to very cumbersome complex measurements. Measurements at frequencies of 30, 50, 150, 450, and 750 Mcps are being made on the high-speed silicon devices discussed above. The manner in which the frequency change affects the results should help in determining whether the effects are caused by using an over-simplified equivalent circuit.

III. MAGNETIC FILM ENGINEERING

A. Clean Room

The installation of the substrate-cleaning equipment is almost complete. Ultrasonic cleaning tanks, a spray-rinse tank, a 5-stage ultrapure water-rinse tank, and a vapor degreaser are installed in a clean work station within the clean room; associated pumps, filter, heaters, and generators are located outside the clean room for maintenance availability. The latter are remotely controlled from within the clean room, as required. The clean room is scheduled to become operational during the next quarter.

B. Pattern Scribing

The Coordinatograph layout machine has been modified to provide for semiautomatic positioning of x- and y-coordinates and generation of pad patterns. Line arrays for the large capacity and associative memory work have been scribed successfully. Line-edge definition is not yet perfect and is limited by the scribing material.

C. Magnetic Film Characteristics

Films described by Kump* as "resilient" have been made by having a high (~30 oe) H_k 100-Å film of CoNiFe on a low H_k (~3 oe) 1000-Å Permalloy film. An extensively tested composite film has $H_k = H_c = 4.6$ oe. It had nondestructive readout capabilities of the full saturation flux for sinusoidal transverse fields between 10 and 25 oe. However, by using unipolar transverse fields, reversibility was limited to an amplitude of 5 oe. Another characteristic of these films is creep disturbing in the presence of a large (10-oe peak) AC transverse field and small (0.1 oe) easy-axis bias. In the limit, 10^5 cycles were required for full switching.

A means of viewing domain walls in films mounted in the paired configuration proposed for the large-capacity memory has been developed by using the Bitter technique. Capacity for simultaneous electromagnetic sensing of the film is being added.

D. Content-Addressed Memory

In order to enable coincident writing with no edge domains, it has been necessary to evaporate the films through masks. The deposition parameters are now being revised so that films with masks will have the same magnetic properties as those made previously without masks. The plane test equipment is operational and is being used to evaluate the utility and uniformity of the films.

E. Large-Capacity Memory

The tester for large-capacity memory substrates is operational with one set of digit circuitry. The signal-to-noise ratio is adequate for testing paired films 500 Å thick. Some experiments have been conducted with both open and closed structures, but no comprehensive testing has been done. Eight digit channels will be added and further changes made for testing the 10.7-inch substrates in place of the present 5-inch units.

An optical comparator has been purchased and a motor-driven X-Y table built to visually inspect the 10.7-inch substrates for deposition and etching imperfections prior to acceptance for pulse testing. Design and construction of a 1-million bit memory stack with pressure connections and diode arrays are progressing.

F. Circuit Design

A circuit has been developed to couple the digit driver and sense amplifier to the combined sense and digit line of the large-capacity memory. Signal-to-"word-noise" ratio is greater than 4:1, recovery from digit-pulse transients less than 1 μsec.

---

*H. J. Kump, "Easy Direction Resilience of Permalloy Film," Proc. Intermag. Conf. (April 1964).

G. Page-Address Memory

Substitution of SPAT circuits for FX-1 circuits, construction of a power controller, and final checkout have been completed. The system is now installed and functioning satisfactorily in TX-2.

IV. SYSTEM PROGRAMMING AND APPLICATIONS

A. Associative Processing

Two aspects of associative memory devices are being investigated. One study concerns the relative efficiency of various schemes for implementing or simulating an associative (content-addressed) memory. The other questions the application of such a device to nonnumerical information processing. This effort is now centered on the development of a programming language for symbol manipulation by means of an associative processor.

B. Graphics

An investigation of the mathematics involved in representing curved lines and surfaces has been initiated so that these functions can be included in the next generation of graphics programs. To display curved objects properly, one must be able to find intersection and tangent curves of quadric surfaces, and perhaps higher-order surfaces. By using homogeneous coordinates, the matrix mathematics are straightforward and it is expected that the hidden-line techniques developed for plane-surfaced objects can be extended to curved surfaces.* One result of interest for display generators is that any conic section can be drawn by using two ratios of three parabolic functions.

C. APEX – Graphics Display Packages

Display packages are now available for use on both the Vector scope and the new curve-drawing scope. The display packages include separate character sets (straight lines only) for both scopes. The character set for the curve-drawing scope will be reworked to use parabolic arcs. A program is being written which will allow specification of parabolics by giving the end points and end slopes, rather than the seven parameters required by the scope.

* L. G. Roberts, "Machine Perception of Three-Dimensional Solids," Technical Report 315, Lincoln Laboratory, M.I.T. (22 May 1963), DDC 413529.

COMPUTER COMPONENTS
GROUP 24

I. MAGNETIC FILMS

A. Theory of Magnetization Ripple

Longitudinal magnetostatic forces (LMF), which arise from poles situated along ripple "walls" and result in a torque that varies as the cube of the ripple amplitude, have been neglected in all the existing theories of magnetization ripple.[1,2,3] It has now been found that for dispersion $\delta \gtrsim 1°$, LMF are of great importance in determining the ripple spectrum, a wholly unexpected result.

The first-order effect of LMF has been found to be a long-wavelength cutoff λ_c such that components with wavelengths $\lambda > \lambda_c$ are completely suppressed, whereas components with $\lambda < \lambda_c$ are unaffected. Wavelength cutoff λ_c is typically one-third the exchange wavelength $2\pi\sqrt{A/K_o}$, and should therefore be the dominant wavelength observed by Lorentz microscopy. Further investigation of LMF is continuing, in particular, its effects on dispersion and on rotational switching.

B. Lorentz Microscopy

A study of the quantitative measurements that can be performed on magnetic thin films in the Lorentz microscope has been undertaken. Such measurements have particular value because insight is provided into the magnetic process of the microscope which occurs in the customary macroscopic magnetic measurements. The measurements include determination of the Curie point, the anisotropy field H_k by both the "standard hysteresigraph"[4] and Feldtkeller[5] techniques, quantitative wall-motion studies of creep and labyrinth propagation, and anisotropy-dispersion measurements by the Crowther[6] and Torok[7] methods. The values of the parameters of a film measured by Lorentz microscopy were very similar to those of a simultaneously deposited film measured by conventional macroscopic techniques. A report of this work is being prepared for the 1965 Conference on Nonlinear Magnetics.

C. Magneto-Optics

A new approach has been made to the design of a magneto-optical light switch by using thin metallic, magnetic films; that is, the phenomenon of total internal reflection is used to provide a "reactive" mirror.

D. Annealing of Permalloy Films

A technique for measuring H_k continuously during perpendicular anneal has been developed which uses the magnetoresistance effect. Initial experiments appear to have yielded a wealth of information regarding the time constants of various atomic processes, which occur during the reorientation of the easy axis during perpendicular anneal. A more precise semiautomatic electronic setup is being constructed to expedite data taking.

II. ELECTRON TRANSPORT

A. Photoelectric Effect in Al-Al_2O_3-Al Diodes

The maximum information regarding the barrier in an Al-Al_2O_3-Al diode would be obtained by measuring the second derivative of the photocurrent with respect to the bias voltage. In principle, such a measurement is possible by modulating the incident light at frequency f_1, the bias voltage at frequency f_2, and detecting a signal at $f_1 + 2f_2$. The circuitry for accomplishing this has been built, but so far no signals have been detected at the desired frequency. However, the parameters of the diode have not yet been optimized with respect to this experiment. Such optimization is presently in progress.

B. Collector Fabrication

In an effort to obtain a low barrier (0.5 volt) for use as a triode collector barrier, we have fabricated thin-film diode sandwiches of gold-CdS-metal wherein the metal is either gold or aluminum. Thicknesses up to 2 microns of cadmium sulfide were evaporated. Either hot substrates of 120° to 170° or subsequent annealing to 300° in vacuum were necessary to achieve a rectifying contact and impedances of 10^7 ohm-cm. Rectification ratios were rather low (10 to 20) and were related to the sulfur vacancies in the film. Postevaporation heat treatments with sulfur and possibly co-evaporation would enable higher rectification ratios. An important feature of this work is that the Schottky barrier formed always faces the lower layer when the counter-electrode follows the heat treatment. Unfortunately, this configuration is not suitable as the collector of a triode.

C. Contact Potential During Al_2O_3 Growth

The large decrease of the work function of aluminum exposed to oxygen pressures in the 10^{-5}-torr region, which was reported in the last quarterly progress report, is apparently due to water vapor. Mass spectrometer analysis showed the principal impurity in the oxygen to be a few percent or less of water, with lesser amounts of CO and CO_2. The CO and CO_2 are believed to be generated by the hot filament of the mass spectrometer[8,9] and cannot definitely be ruled out. Separate experiments, which involve the direct introduction of water vapor, have shown that a one-volt lowering of the work function of a freshly deposited aluminum surface occurs in a few minutes when exposed to a pressure of 10^{-7} torr. Similarly, a one-volt lowering of an aluminum surface previously exposed to oxygen occurs in a few minutes at a water pressure of 10^{-8} torr. The water vapor contaminant in the oxygen is produced within the vacuum system, since the initial oxygen fed into the system contains less than a few parts per million of water. It apparently occurs in interaction with the Vac Ion pump or with a hot filament, since the one-volt lowering of the work function was not observed upon bleeding in oxygen with the pump and ion gauge off. The role of water vapor as a contaminant that produces such large work-function changes has apparently not been appreciated in the literature. Its role in accelerating the growth of Al_2O_3 may be simply due to the lowering of the work function, thereby paving the way for adsorbed oxygen to create a more negative surface potential, which in turn causes an increased field to pull the aluminum ions through the growing oxide film.

For small quantities of water vapor and short exposure times, the work function of the gold reference heat is stable; however, for the long times and high exposures (18 hours, 1 to 2 percent H_2O) needed to make practical thicknesses of oxide, the gold reference changes 0.2 to 0.4 volt. Hence, it will be necessary to investigate other methods of oxidation in the future.

D. Hot Carriers in Transistors

Work has begun on the hot carrier effects in transistors. In most modern transistors, the field in the collector transition regions is sufficiently intense ($> 10^4$ volt/cm) to heat the carriers to approximately 500° + 600°K, while in adjacent regions the fields are small enough for the carrier to remain in thermal equilibrium with the lattice. Consequently, at the boundaries between regions of normal and hot carriers, charge transport due to the carrier temperature gradient may represent a significant portion of the total current in the region of the boundary. If such conditions exist in transistors, the boundary conditions for the solution of charge transport in various regions of the transistor will have to be revised.

REFERENCES

1. H. Rother, Z. Physik 168, 42 (1962).
2. H. Hoffmann, J. Appl. Phys. 35, 1790 (1964).
3. K. J. Harte, thesis, Harvard University (1964).
4. D. O. Smith, J. Appl. Phys. 29, 264 (1958).
5. E. Feldtkeller, Physics Letters 7, 9 (1963).
6. J. I. Raffel, T. S. Crowther, A. H. Anderson, and T. O. Herndon, Proc. IRE 49, 153 (1961).
7. E. J. Torok, R. A. White, A. J. Hunt, and H. N. Oredson, J. Appl. Phys. 33, 3037 (1962).
8. J. R. Young, J. Appl. Phys. 30, 1671 (1959).
9. J. S. Wagener, and P. T. Marth, J. Appl. Phys. 28, 1027 (1957).

PSYCHOLOGY
GROUP 25

I. AUTOMATIC PROCEDURE EXECUTOR

Detailed specifications of all major parts of the APEX system for the TX-2 computer are now complete; the past quarter has been devoted principally to coding and debugging. A preliminary version consisting of parts of the Secretary and Maestro is now operating and is designed to evolve gracefully into the final system, as the various parts become available. In addition to work on APEX itself, some work has been done on service programs for operation within the APEX structure; one useful library routine is operating with the system.

A. Status of Five Major Parts of APEX

The Secretary, which handles interrupts and input-output transfers, is well along with coding and debugging. Routines for the Xerox, photoelectric tape reader, IBM tape, and a single keyboard-typewriter are operating. These routines work in the present version of the system, but will require some extension when the Csar is integrated into the system. The Xerox routine is being expanded to increase the protection against illegal requests and revised to improve the efficiency of interleaving with other routines. Work on the paper-tape punch routine has been deferred and is about to resume. An attempt to integrate the existing display routines into the system will be made soon.

The Maestro determines which user, interrupt, or alarm is to be handled next. The main effort has been on consolidation of the Maestro and other executive programs to produce intermediate versions of APEX which will allow testing as much of the system as may be available. These developments include adapting the system to hardware improvements, advances in the design of existing programs, and the introduction of new executive routines. The first such "system package" was completed at the beginning of this reporting period, the second has just been finished, and the third is in progress. Further changes are expected at frequent intervals, and a special effort has therefore been made to document the coding.

The Csar (core storage allocation routine) does the bookkeeping needed in sharing time, space, and programs. Checkout has been completed on most of the section that processes requests from users. A timing analysis was made on these routines and new tactics have been implemented which substantially reduce the running time. Coding has been virtually completed on the set of routines which control the page-address memory (PAM). Flow charting continues on the package of routines which allocates and retrieves actual core storage.

The Mover transfers information to and from the auxiliary file memory. Work has been deferred until the arrival of the page-address and memory-snatch hardware. Most of the hardware is now available, and work should resume soon.

The Librarian maintains the directories of users and public files. It has been specified. Coding, which will be undertaken by Group 23, should begin in the near future.

B. Related Routines

The library routine that is already operating types a list of the files on APEX-format IBM tape, and it types information about bad blocks found on the tape. A basic translator for commands typed on-line and a number-conversion routine have been specified in cooperation with Group 23 staff, who will do the coding. Service routines that handle the parameters of subroutines are in progress.

II. HUMAN INFORMATION PROCESSES

A. Multidimensional Scaling

Work on the use of monotone transformations in multidimensional scaling has been concluded. The computer programs have been cleaned up and annotated. They include, in addition to programs that have been mentioned before, programs that will:

(1) Aid in the design and execution of multidimensional scaling experiments,

(2) Examine individual differences in ways of judging similarity,

(3) Rotate a configuration in r dimensions to match another in s dimensions, where $r \geq s$.

A final series of computer runs was made to compare other multidimensional scaling procedures* with the one developed here.

B. Short-Term Recall†

Data have been collected on the recall of groups of five common nouns presented 1, 2, 3, or 4 times. The five words were presented visually and simultaneously. In one case, the order of the words varied from presentation to presentation; in the other, it was constant. The time between presentations was varied from 0 to 16 seconds, and the time from the last presentation to the signal for recall was varied independently over the same range. During both these intervals, the subject engaged in a number-reading task to minimize rehearsal of the words. The data pose, in particularly clear form, an important paradox: increasing the interval after a presentation can improve the ability to utilize another presentation at the end of the interval, but it degrades recall on a test given at the end of the interval. An analysis of kinds of errors is being made.

C. Discrimination of Recency†

Yntema and Trask‡ have shown that when presented with a long series of unconnected words, subjects have considerable ability to discriminate which of two words was presented more

---

* R. N. Shepard, "The Analysis of Proximities: Multidimensional Scaling with an Unknown Distance Function," Psychometrica 27, 125 and 219 (1962). J. B. Kruskal, "Multidimensional Scaling by Optimizing Goodness of Fit to a Nonmetric Hypothesis," Psychometrica 29, 1 (1964).

† One of the investigators was a National Institutes of Health postdoctoral fellow.

‡ D. B. Yntema and Frances P. Trask, "Recall as a Search Process," J. Verbal Learning and Verbal Behavior 2, 65 (1963).

recently. Interpretation of the results was to some degree ambiguous, because the subjects were at times unable to recognize whether the words had been presented at all. It would therefore be desirable to find a class of stimuli that would allow the discrimination of recency to be investigated without the complications which arise from difficulties of recognition. Preliminary tests indicate that a large collection of pictures cut from magazines may be the answer to the problem.* The recognizability of the pictures appears to be high. The data also suggest that with these stimuli, the discrimination of the recency is remarkably good.

D. Perceptibility and Memorability

In an experiment described in the last quarterly progress report, two garbled speech sounds were presented about a second apart; the subject was to say whether the sounds were the same. It was found that when the first garble (the sound that was to be remembered for a short period) was presented in noise, performance was poorer than in a control condition in which the second garble was presented in the same amount of noise – a finding that is not immediately compatible with results obtained when short-term retention of degraded stimuli was tested by recall. Two further experiments have now extended this finding to other noise levels and to a longer interval (about 5 seconds) between the garbles.

*The pictures were lent by Dr. R. N. Shepard of the Bell Telephone Laboratories.

CONTROL RESEARCH
GROUP 28

I. HYBRID COMPUTER SYSTEMS

The development of the on-line hybrid computing facility is continuing with emphasis on programming and analysis, design and construction, and research applications.

Mapping and scaling algorithms have been worked out and a detailed plan for a compiler program has been developed. This program will operate on a large time-shared general-purpose computer and will enable the user to enter his problem in a format like that of the original differential equations. Automatic setup of the digital differential analyzer (DDA), including mapping and scaling, is then performed under program control.

A study of errors in incremental computations has been started. In addition to the usual errors associated with numerical methods (such as the use of discrete independent variables and quantization of the dependent variables), the use of increments of the dependent variable rather than full words, as well as the special types of arithmetic operations in the DDA, lead to special error characteristics. These studies are being carried out on a simulation of the DDA programmed on a time-shared system.

The construction of the DDA is continuing and the Y- and R-registers and their respective adders are now complete. Construction of the 256-bit shift register and Q-register has started and installation of the core memory will be on schedule. One design change in the DY selection logic has been made which now allows complete programmed interconnection of the 256 integrators.

A study of incremental computer configurations has been made to indicate possible design improvements. Various designs have been examined to show the relations between types of memory (magnetic drum, magnetic core, magnetic thin films, ultrasonic delay lines, and flip-flop), the type of arithmetic (series, parallel), and the generation of the integrator outputs (sequential, sequential-simultaneous, simultaneous). The results show that it is possible to build DDA's by using 20-Mcps ultrasonic delay lines with iteration rates of 7.5 to 17 kcps for 200 to 300 integrators, with complete interconnection under program control.

Two studies have been completed which show how the hybrid computer (LINC/DDA) can be used for re-entry vehicle trajectory generation and for on-line spectral analysis of radar data. In both cases, the combination of automatic setup and on-line use of displays leads to new possibilities in studying intercept strategies and effects of window widths, nonstationarity, and smoothing times.

II. ESTIMATION AND CONTROL STUDIES

Designs of recursive, real-time algorithms for processing metric radar data have been documented.* Similar types of recursions are presently being investigated for estimating the

*F. C. Schweppe, "Algorithms for Estimating a Re-Entry Body's Position, Velocity and Ballistic Coefficient in Real Time or for Post Flight Analysis," Group Report 1964-64, Lincoln Laboratory, M.I.T. (3 December 1964), DDC 609524.

frequency of a sine wave. Such techniques are valuable when using a digital computer for estimating Doppler shift.

The use of the hybrid computer for performing power spectrum analysis is being investigated. The potentials of differential equation models combined with the hybrid facilitiy's on-line display and parameter variation capabilities make this approach very promising. The possibilities of processing data from an array of seismometers on the hybrid computer are also encouraging.

Signal design studies have centered on the properties of a matrix differential equation of the Ricatti type. This equation governs the information content of wide classes of signals and is considered a system which is to be controlled by the choice of the signals.

DOCUMENT CONTROL DATA – DD 1473

1. ORIGINATING ACTIVITY Lincoln Laboratory, M. I. T.	2a. REPORT CLASSIFICATION Unclassified 2b. DOWNGRADING GROUP

3. REPORT TITLE
Division 2 Quarterly Progress Report on Data Systems

4. TYPE OF REPORT AND INCLUSIVE DATES
Quarterly Progress Report for 1 November 1964 through 31 January 1965

5. AUTHOR(S) *(Last name first)*
Frick, F. C.

6. REPORT DATE	7a. NO. OF PAGES	7b. NO. OF REFS.
15 February 1965	24	15

8a. CONTRACT NO. AF 19(628)-500	9a. ORIGINATOR'S REPORT NO. Div. 2 QPR for 2/15/65
8b. ORDER NO. None	9b. OTHER REPORT NO(S). ESD-TDR-65-47

10. AVAILABILITY OR LIMITATION NOTICES

11. SUPPLEMENTARY NOTES None	12. SPONSORING ACTIVITY ESD

13. ABSTRACT

This report reviews progress during the period 1 November 1964 through 31 January 1965 for the General Research Program of Division 2. Separate progress reports on the Ballistic Missile Re-entry Systems, Project Apollo, and Project PRESS describe other work in the Division.

Detailed reports of research will continue to be available in the form of Technical Reports, Technical Notes, and Journal Articles. A list of the reports issued during the present reporting period is included herein.

14. KEY WORDS

computers
circuits and components
display systems
election transport
magnetic films
programming
psychology
control systems

Printed by
United States Air Force
L. G. Hanscom Field
Bedford, Massachusetts